Analysis of THD and Harmonics in 3 Level Inverter with LC filter

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Abstract: In the paper a simulation work is carried out on three level multilevel inverter. The major application of the inverter is driving the induction motor at variable speeds. The harmonics produced in the inverter are the major cause of heat produced in the induction motor. These harmonics are to be eliminated or suppressed, this is achieved by using the LC filter. An LC filter is a simple filter but proves to be very effective in the suppression of harmonics. Variation of total harmonic distortion in both cases of with and without filter are studied. The filter at the output of inverter will cause the voltage to drop. The output voltage varies with filter, an optimized value of the filter value is obtained and studied its THD and Harmonic order at the output of the 3-level inverter and compared with LC filter, the results presented in this simulation work.

Keywords: Multilevel inverter, Three Level Inverter, THD, Harmonics, LC Filter.

I. INTRODUCTION

The three phase induction motor is the work horse of the industries. The inverters are constructed with IGBT modules or intelligent modules used to drive the three phase induction motor. The major usage of the induction motor in industries is for variable speed applications. The variable speed of the motor is achieved by providing control signals to the PWM inverter drive. The inverter drive the induction motor with variable speed using different techniques. The most common method for using variable speed is voltage/frequency method. The research work is being done in this area for the achievement of the better control and reduction of harmonics. The major concern of using an inverter is that it produces odd harmonics. Harmonic is defined as a sinusoidal component of a periodic wave having a frequency that is an integral multiple of the fundamental frequencies. The total harmonic distortion (THD) is the percentage of harmonics in a AC circuit output waveform. THD is expressed in percentage with respect to the value of fundamental current or voltage. The three level – multilevel inverter is used to control the AC load in this work. The three-level inverter is widely used in high voltage, high power applications due to its high voltage handling and good harmonic rejection capabilities with currently available power devices. The multilevel inverter has an output more sinusoidal than the traditional PWM inverter drive (two level inverter). The three-level inverter roughly improves by a factor of four times of the harmonics content compared with conventional two-level topology having the same number of devices and ratings. This allows the researchers to use filters with lesser values than using bulky filters to modify the output. If the filters are bulky the circuit becomes bulky and expensive. Both of them are not accepted by the industries or any other user even the researchers. The filter has to be always simple and affective. This will achieve the goal of keeping the circuit less complicated and light weight. There are many kinds of filters, in this paper a simple LC filter is used. The multilevel output of the inverter provides an output that can be easily converted into an sinusoidal output. The inverter generates odd harmonics 3rd, 5th, 7th, 9th, 11th, 13th etc. Triplet harmonics are absent in Three phase inverter 3rd, 9th, 15th etc. the only harmonics present at the output of the inverter are 5th, 7th, 11th, 13th etc. The theoretical maximum amplitude of each harmonic produced by a converter is equal to that of the fundamental component divided by the harmonic order. For example, the 5th harmonic is equal to 20% of the load current and the 7th harmonic is equal to 14.3% and so on. The voltage/frequency(V/f) method is preferred over other speed varying techniques, it can be easily achieved and can be easily understood by the user of the inverter at an industry. The motors rated V/F is calculated then in relation to that the frequency at which it has to driven is fixed and the voltage is calculated. The V/F constant is different of each induction motor. This calculation is much simpler than most other methods. The automation of this method is also simple and can be achieved easily. The inverter type used in this work is an voltage source inverter.

II. CIRCUIT AND WORKING

A. Multi Level Inverter- Three level:

The Three level inverter drive has 12 switches. The Fig.1 shows the circuit diagram of the three level inverter drive. The IGBT's are used as switches, gating signal to each switch is provided through a pulse generator. Each phase is 120° out of phase with each other. The Sb-1 is turned on with a phase delay of 120° with respect Sa-1, similarly Sc-1 is tuned on with a phase delay of 120° with respect Sb-1. The switches Sa2, Sb2 and Sc2 are turned on with a delay of 10° with reference to switches Sa1, Sb1 and Sc1 respectively and are ON for a duration of 160°. Sa1, Sb1, Sc1, Sa2, Sb2 and Sc2 are the upper switches and switches Sa1’, Sb1’, Sc1’, Sa2’, Sb2’ and Sc2’ are the lower switches. All the lower switches are the compliments of their respective upper switch. Sa1’, Sb1’, Sc1’, Sa2’, Sb2’ and Sc2’ are the compliments of Sa1, Sb1, Sc1, Sa2, Sb2 respectively. At any instant of time no two switches in the upper group and lower group in the same leg can be ON. The switching pattern of the


30
switches are one pair from the lower group and two pair from the upper group or one pair from the upper group and two pair from the lower group are ON. This produces a three phase three level output power used to drive the load. The RL Load with values \( R=11\Omega \) and \( L=43.7\text{mH} \). The input resistor \( R=0.1\Omega \), \( C1=C2=1000\mu\text{F} \), \( V_{in}=100\text{V} \).

Fig 1: Three level inverter drive with RL Load

B. Multi Level Inverter- Three level with LC Filter:
The multi level – three level inverter is introduced with a LC filter at its output. The circuit is has shown in Fig-2. The filter reduces the harmonic content at the output of the inverter and the output of the three level inverter becomes a sinusoidal output. The filter consists of a inductor \( L \) for each phase and three capacitor which are connected between each phases. The capacitor value is kept constant at 1000 \( \mu\text{F} \). The value of the inductance is varied to obtain results.

Fig 2: Three Level Inverter with LC filter

III. RESULTS

The analysis of simulation of the circuits in Fig.1 and Fig.2 are carried out in this paper. The results are obtained after repetitive trials and its values to all the LC filter elements. The output line to neutral voltage of the circuit in Fig.1 with R Load is as shown in Fig.3.

Fig 3: Line to neutral voltage wave form of 3 Level Inverter Drive with R load.

Fig 4: Line to neutral voltage wave form of 3 Level Inverter Drive with RL load.
The output line to neutral voltage of the circuit in Fig.2 with RL Load is as shown in Fig.4. The line current of the 3 level inverter, shown in Fig.5 with R load.

Fig 5: Line current wave form of 3 Level Inverter Drive with R load.

The harmonics plot of line to neutral voltage of three level inverter drive with RL load is as shown in Fig.9.

Fig 9: Harmonics plot of line to neutral voltage of 3 level inverter.

The harmonics plot of line current of three level inverter drive with RL load is as shown in Fig.10.

Fig 10: Harmonics plot of line current of three level inverter.

The output line to neutral voltage and line current with RL load are as shown in Fig.7 and Fig.8 respectively with LC filter where L=6mH and C=1000µF.

Fig 7: Line to neutral voltage wave form of Three Level Inverter Drive with RL load with LC filter.

Fig 8: Line current wave form of Three Level Inverter Drive with RL load with LC filter.

Fig 11: Harmonics plot of line to neutral voltage of three level inverter with LC filter.
Fig 12: Harmonics plot of line current of three level inverter with LC filter.

The Fig.11 and Fig.12 shows the plot of harmonics of line to neutral voltage and line current respectively with LC filter. For different filter inductance values the simulation is carried out with Capacitor value constant. CC1=CC2=CC3=1000µF. The Total Harmonic Distortion (THD) for these inductance values are noted. The results are tabulated in table.1. The table has the values of line to neutral voltage, line current and the THD in % for both voltage and current.

Table 1: THD in percentage for Voltage and Current with and without filter

<table>
<thead>
<tr>
<th>Filter with L in mH</th>
<th>THD in % for Voltage with L in mH</th>
<th>THD in % for line C</th>
<th>Voltage in V</th>
<th>Current in A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without filter</td>
<td>32.44</td>
<td>8.07</td>
<td>63.1</td>
<td>3.59</td>
</tr>
<tr>
<td>5mH</td>
<td>0.82</td>
<td>0.5</td>
<td>151.8</td>
<td>8.64</td>
</tr>
<tr>
<td>6mH</td>
<td>1.23</td>
<td>0.59</td>
<td>89.82</td>
<td>5.17</td>
</tr>
<tr>
<td>7mH</td>
<td>1.4</td>
<td>1.16</td>
<td>64.88</td>
<td>3.69</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

The three phase three level inverter drive circuit has been constructed with simulink Matlab and simulation work has been carried out. The harmonics and the THD of both line current and line to neutral voltage are studied. The output of the inverter with the filter is found to be sinusoidal and the magnitude of the harmonics has been drastically reduced. The different inductor values in the filter provide current and voltage THD. As the inductance is increased the THD is increased and the magnitude of voltage and current is decreased. The lower values of L provide for better THD and magnitude. The even harmonics are also present which are also minimized using LC filter.

REFERENCES


